



UTILITY PATENT APPLICATION TRANSMITTAL

Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.

35.G2360

First Named Inventor or Application Identifier

JUN NITTA

Express Mail Label No.

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO:

Assistant Commissioner for Patents
Box Patent Application
Washington, DC 20231

1. ☐ Fee Transmittal Form
(Submit an original, and a duplicate for fee processing)

2. ☒ Specification Total Pages

3. ☒ Drawing(s) (35 USC 113) Total Sheets

4. ☒ Oath or Declaration Total Pages

a. ☒ Newly executed (original or copy)

b. ☐ Unexecuted for information purposes

c. ☐ Copy from a prior application (37 CFR 1.63(d))
(for continuation/divisional with Box 17 completed)
[Note Box 5 below]

i. ☐ **DELETION OF INVENTOR(S)**
Signed Statement attached deleting
inventor(s) named in the prior application,
see 37 CFR 1.63(d)(2) and 1.33(b).

5. ☐ Incorporation By Reference (useable if Box 4c is checked)
The entire disclosure of the prior application, from which a copy of
the oath or declaration is supplied under Box 4c, is considered as
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6. ☐ Microfiche Computer Program (Appendix)

7. Nucleotide and/or Amino Acid Sequence Submission
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a. ☐ Computer Readable Copy

b. ☐ Paper Copy (identical to computer copy)

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ACCOMPANYING APPLICATION PARTS

8. ☒ Assignment Papers (cover sheet & document(s))

9. ☐ 37 CFR 3.73(b) Statement ☐ Power of Attorney
(when there is an assignee)

10. ☐ English Translation Document (if applicable)

11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations

12. ☐ Preliminary Amendment

13. ☒ Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)

14. ☐ Small Entity Statement(s) ☐ Statement filed in prior application
Status still proper and desired

15. ☐ Certified Copy of Priority Document(s)
(if foreign priority is claimed)

16. ☐ Other: _____

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No. ____/____

18. CORRESPONDENCE ADDRESS

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CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS (37 CFR 1.16(c))	24-20 =	4	X \$ 18.00 =	\$ 72.00
	INDEPENDENT CLAIMS (37 cfr 1 16(b))	5-3 =	2	X \$ 78.00 =	\$156.00
	MULTIPLE DEPENDENT CLAIMS (if applicable) (37 CFR 1.16(d))			\$260.00 =	\$
				BASIC FEE (37 CFR 1.16(a))	\$760.00
			Total of above Calculations =		\$988.00
	Reduction by 50% for filing by small entity (Note 37 CFR 1.9, 1.27, 1.28).				-
	TOTAL =				\$988.00

19. Small entity status

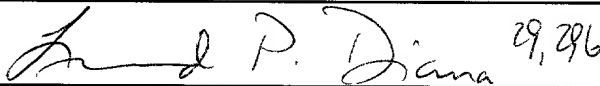
- a. ☐ A Small entity statement is enclosed
- b. ☐ A small entity statement was filed in the prior nonprovisional application and such status is still proper and desired.
- c. ☐ Is no longer claimed.

20. ☒ A check in the amount of \$ 988.00 to cover the filing fee is enclosed.

21. ☐ A check in the amount of \$ _____ to cover the recordal fee is enclosed.

22. The Commissioner is hereby authorized to credit overpayments or charge the following fees to Deposit Account No. 06-1205:

- a. ☒ Fees required under 37 CFR 1.16.
- b. ☐ Fees required under 37 CFR 1.17.
- c. ☐ Fees required under 37 CFR 1.18.

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED	
NAME	LEONARD P. DIANA
SIGNATURE	 29,296
DATE	March 12, 1999

1 TITLE OF THE INVENTION

Laser With Phase Controlling Region And Method For
Driving the Same

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a laser, such as
a distributed feedback (DFB) semiconductor laser
capable of switching a polarization mode of its output
10 light between two polarization modes (typically, transverse
electric (TE) mode and transverse electric (TM) mode)
depending on its driven condition, and relates to a
method of driving that laser and to an apparatus or system
including the laser.

15 Related Background Art

Conventionally, Japanese Patent Application
Laid-Open No. 7(1995)-162088, for example, discloses
a polarization-mode switchable DFB semiconductor laser
with plural electrodes in which the relation between
20 a wavelength dispersion of a gain created by its active
layer and a Bragg wavelength determined from a pitch
of its diffraction grating and so forth, is controlled.

Fig. 1 illustrates a conventional structure of such
a type. Fig. 1 is a cross-sectional view taken along a
25 laser resonance (cavity-axial) direction of the DFB
semiconductor laser. The structure includes a lower
clad layer 1010, an active layer 1011, a light guide

1 layer 1012, an upper clad layer 1013, and a contact
layer 1014 which are laid down over a substrate 1009, in
this order. A diffraction grating 1020 is formed at the
interface between the light guide layer 1012 and the
5 upper clad layer 1013. The contact layer 1014 is
divided into two portions along the resonance direction.
Electrodes 1002 and 1003 are respectively deposited
on the two portions of the contact layer 1014, and an
electrode 1008 is formed on the bottom surface of the
10 substrate 1009. Currents can be independently injected
into two active regions under the electrodes 1002
and 1003, which are electrically independent from each
other along the laser resonance direction. An antireflection
layer 1004 is provided on an end facet of the laser, and
15 a separating groove 1015 is formed between the two active
regions.

In the conventional structure, the active layer 1011
is formed of a quantum well structure of AlGaAs and
GaAs. The Bragg wavelength of the grating 1020 is set
20 at a value shorter than a peak wavelength of the gain
spectrum for the TE mode. Thus, a polarization-mode
contention condition can be created between the TE mode
and the TM mode. A ratio between the currents injected
into the two active regions can be controlled, so that
25 the polarization mode of its oscillated output light can
be switched between the TE mode and the TM mode.

Further, Japanese Patent Application Laid-Open

1 No. 2(1990)-159781 discloses a three-electrode DFB
semiconductor laser with a $\lambda/4$ phase shift section
in its diffraction grating, which can switch the polarization
mode of its output light between the TE mode and the TM mode.
5 The semiconductor laser includes a structure in which
currents can be independently injected into a region
with the $\lambda/4$ phase shift and a region without it. The
 $\lambda/4$ phase shift section is formed in a central portion, and
currents can be independently injected into the central
10 portion and two remaining portions on both opposite sides
thereof. When the current injected into the central region
with the $\lambda/4$ phase shift is changed under a uniform
current injection condition, the oscillation
polarization mode can be switched between the TE mode
15 and the TM mode.

Furthermore, Japanese Patent Application Laid-Open
No. 8(1996)-172234 discloses a polarization-mode
switchable semiconductor laser with a phase controlling or
adjusting region lacking a diffraction grating and an
20 active layer, in which a difference of about π is
generated between phase changes for the TE mode and the
TM mode in the phase controlling region. The polarization
dependency of the amount of the phase change is thus
set such that the oscillation polarization mode can be
25 stably switched.

Each of the above structures effects the
polarization switching when its light circulation phase

1 is changed. Further, each has a structure satisfying the
following condition: While the mode is being changed to
a mode whose circulation phase differs from the present
mode by 2π , for the same polarization mode (for example,
5 TE mode), the circulation phase of light in the other
polarization mode (for example, TM mode) comes to satisfy
the resonance condition and the pumping amount comes
to reach its threshold gain. For this purpose, a
strained quantum well is used in the conventional structure,
10 for example. This approach can also be used in the
present invention.

However, in the conventional polarization-mode
switchable DFB laser with the phase adjusting region
wherein a diffraction grating region and a phase
15 adjusting region are arranged serially, a sufficient
effect of light adjusted in the phase adjusting region
often cannot be obtained when light is only weakly
returned from the phase adjusting region, or when the
coupling coefficient of the diffraction grating is large
20 and thus its reflection factor is high.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide
a laser, such as a distributed feedback semiconductor
25 laser, which is constructed such that light influenced
by its phase controlling or adjusting region can readily
influence a region adjacent to the phase controlling

1 region effectively, and to a driving method for driving
the laser, a light transmitter using the laser, and
an optical transmission system or method using the
laser.

5 The object of the present invention is achieved by
the following lasers, driving methods, transmitters and
optical communication systems or methods.

A laser of this invention includes a first region
with a first waveguide having a first diffraction
10 grating, a second region with a second waveguide having
a second diffraction grating, and a phase controlling
region with a third waveguide and a phase control unit
for controlling an effective refractive index of the
third waveguide. The phase controlling region, the
15 first region and the second region are serially
coupled along a light propagation direction in this
order, and are constructed such that light to the first
region from the phase controlling region is enlarged
relatively to light to the phase controlling region from
20 the first region, or constructed such that a coupling
coefficient of the first diffraction grating in the first
region adjacent to the phase controlling region is
smaller than a coupling coefficient of the second
diffraction grating in the second region.

25 The effect or performance of the phase controlling
region is enhanced, and hence the modulation of
polarization-mode or wavelength can be effectively

1 achieved stably. Further, the action of the phase controlling
region can be effectively employed by making the coupling
coefficient in the first region adjacent to the phase
controlling region smaller than the coupling coefficient
5 in the second region away from the phase controlling
region, though the coupling coefficient of the region
other than the phase controlling region is not decreased
uniformly.

More specifically, the following structures may be
10 adopted based on the above fundamental structures.

A coupling coefficient of the first diffraction
grating in the first region adjacent to the phase
controlling region may be set smaller than a coupling
coefficient of the second diffraction grating in the
15 second region. In this structure, the grating region with
the smaller coupling coefficient allows a large change of
light at a wavelength at which phases of light travelling
from the phase controlling region and light reflected
in the grating region with the smaller coupling
20 coefficient coincide with each other, by the control of
the phase of light in the phase controlling region.
Accordingly, a resonance wavelength balancing in three
regions of the regions with large and small coupling
coefficients and the phase controlling region can be
25 largely changed by the change of the index in the phase
controlling region due to the control of current injection,
voltage application or the like. As a result, the effect

1 of the phase controlling region can be enhanced, and
hence the modulation of polarization mode or wavelength
can be effectively and stably achieved. The feature
of this structure is that the grating region is devised
5 such that light influenced by the phase controlling
region can readily influence the grating region adjacent
to the phase controlling region.

Further, the following specific structures may be
used as a structure for making light to the first region
10 from the phase controlling region larger than light
to the phase controlling region from the first region.

The first region includes a first control unit for
pumping the first region, and the phase control unit and
the first control unit are capable of independently
15 controlling the phase controlling region and the first
region, respectively. In this structure, a feedback
function of the region adjacent to the phase controlling
region is weakened relatively to that of the other
region, so that the influence of light from the phase
20 controlling region can be readily increased. As a
result, the effect of the phase controlling region can
be enhanced, and hence the modulation of polarization mode
or wavelength can be effectively and stably achieved.
The feature of the structure is that a feedback to
25 the region adjacent to the phase controlling region
due to the gain can be decreased.

The laser may be typically constructed as a

1 distributed feedback semiconductor laser. In this case,
the phase controlling region may include a cleaved
end facet. A reflective layer may be provided on the
cleaved end facet. In this structure, the end facet with
5 a large reflection factor can be used, different from
a case where the phase controlling region is arranged
near a central portion of the DFB laser, and thus the
effect of the phase controlling region can be further
increased.

10 According to still another aspect of the present
invention, there is provided a method for driving a laser
in which a current injected into or a reverse voltage
applied to the phase controlling region is changed to
change at least one of a polarization mode and a waveguide
15 of light output from the laser.

According to still another aspect of the present
invention, there is provided a light transmitter which
includes the above laser, a control unit for controlling
light output from the laser in accordance with a
20 transmission signal, and a mode selector for selecting
a component of a desired mode from the light output from
the laser. The mode selector may be a polarization-mode
selector or a wavelength selector.

According to still another aspect of the present
25 invention, there is provided an optical communication
system for communicating over a light transmission line
that transmits a signal from a transmitter side to

1 a receiver side, in which light of a signal from the
above transmitter is transmitted through the light
transmission line, and a receiver receives and detects
an intensity-modulated signal transmitted from the
5 transmitter through the light transmission line. The
system may be a wavelength division multiplexing optical
communication system, in which a light transmission line
transmits a plurality of intensity-modulated signals at
a plurality of wavelengths generated by a plurality of
10 the above transmitters, and a wavelength selector, such
as a tunable band-pass filter, selects the intensity-
modulated signal at a desired wavelength to be detected
on a receiver side.

These advantages and others will be more readily
15 understood in connection with the following detailed
description of the preferred embodiments in conjunction
with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

20 Fig. 1 is a cross-sectional view illustrating a
conventional DFB semiconductor laser.

Fig. 2 is a cross-sectional view illustrating a
first embodiment of the present invention, which is a DFB
semiconductor laser, taken along its cavity-axial
25 direction.

Fig. 3 is a perspective view illustrating the first
embodiment.

1 Fig. 4 is a cross-sectional view illustrating a
second embodiment of the present invention, which is a DFB
semiconductor laser, taken along its cavity-axial
direction.

5 Fig. 5 is a block diagram illustrating a third
embodiment of the present invention which is directed
to a light transmitter with a laser of the present
invention.

10 DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

A first embodiment of a DFB semiconductor laser is
illustrated in Fig. 2. As illustrated in Fig. 2, a buffer
layer 2 of n-InP, an active layer 3, a refractive-index
controlling layer 4, a light guide layer 5 of undoped
15 InGaAsP, a clad layer 8 of p-InP, and a contact layer 9
of p-InGaAs are laid down over a substrate 1 of n-InP
in this order. First and second diffraction gratings 6
and 7 are formed at the interface between the light guide
20 layer 5 and the clad layer 8. Further, first and second
electrodes 10 and 11 are deposited on divided portions
of the contact layer 9, and a third electrode 12 is
formed on the bottom surface of the substrate 1. An
antireflection layer 13 is provided on an end facet of
25 a region with the first and second gratings 6 and 7 of
the laser, and a reflective layer 14 is formed on an end
facet of a region lacking the grating. A separating

1 groove 15 is formed between the first and second
electrodes 10 and 11 for the purpose of electric
separation.

In the above structure, a region under the first
5 electrode 10 is a DFB laser region 22, and a region under
the second electrode 11 is a phase controlling or
adjusting region 23. In the DFB laser region 22, there
are arranged a high- κ region 20 corresponding to
a portion with the first diffraction grating 6 having
10 a relatively large coupling coefficient κ and a low- κ
region 21 corresponding to a portion with the second
diffraction grating 7 having a relatively small coupling
coefficient κ . The positional relation between those
four regions 20-23 is indicated in Fig. 2.

15 Fig. 3 illustrates a perspective view of the first
embodiment. As illustrated in Fig. 3, a burying
structure of burying layers 16 is employed as a confining
structure in a direction transverse to a light propagation
direction. The burying layer 16 may be a high-resistance
20 layer, a p-n burying layer, or the like. The waveguide
structure of the laser is not limited to the illustrated
one, but any structure, such as a ridge type and
an electrode-stripe type, can be used provided that it
can be used in the semiconductor laser.

25 The phase adjusting region 23 is coupled to the
low- κ region 21 with the second grating 7 in the DFB
laser region 22. Pitches of the first and second

1 gratings 6 and 7 are set to a common value of 243 nm,
while depths thereof are varied such that the first
and second gratings 6 and 7 can have the above
coupling coefficients. Specifically, the larger coupling
5 coefficient of the first grating 6 is approximately
set to 80 cm^{-1} , while the smaller coupling coefficient
of the second grating 6 is approximately set to 30 cm^{-1} .
The longitudinal length of each of the high- and low- κ
regions 20 and 21 is set to $200\text{ }\mu\text{m}$, and the length
10 of the phase adjusting region 23 is set to $150\text{ }\mu\text{m}$.

The reflective layer 14 is formed on the end
facet of the phase adjusting region 23 to enhance the
effect of the phase adjusting region. The antireflection
layer 13 is formed on the end facet of the high- κ
15 region 20 so that an inherent operation of the DFB
laser region 22 can be secured. Influences of
variation are eliminated among end facets of the first
diffraction gratings 6 of individual devices, which
variation is due to the process of cleaving the device.

20 The active layer 3 has approximately the same
amplification factor for the TE-mode light and the
TM-mode light propagating along the waveguide. In this
embodiment, a 0.6 %-tensile-strained quantum well layer
is used as the active layer 3 to achieve a desired
25 characteristic for light at a wavelength of about $1.55\text{ }\mu\text{m}$.
The quantum well layer has a well width of 13 nm, a
barrier width of 10 nm, and a barrier-composition

1 wavelength of $1.17\ \mu\text{m}$. The index controlling layer 4
is formed of material whose bandgap wavelength is set to
about 50 nm shorter than the wavelength of light
oscillated in the DFB laser region 22.

5 The operation of the first embodiment will be
described. When a forward bias is applied across the
first electrode 10 and the third electrode 12, oscillation
of the DFB laser occurs above a certain current amount.
In this case, the circulation phase of light oscillated
10 in the cavity satisfies the oscillation condition. Here,
the circulation phase is a phase shift that the light
shows when the light circulates once in the cavity. In
this state, when a current is injected into the phase
adjusting region 23 across the second and third
15 electrodes 11 and 12 to change the effective refractive
index of the waveguide in this region 23, the phase
will be changed in light reflected by the reflective
layer 14 and returning to the DFB laser region 22. As
a result, the oscillation wavelength prior to the current
20 injection into the region 23 comes to deviate from the
circulation-phase condition and light thereat ceases.
Thus, the oscillation mode turns to another wavelength
or polarization mode that satisfies the circulation-phase
condition.

25 A change of the refractive index in the phase
adjusting region 23 occurs for each of the TE mode and
the TM mode. Accordingly, when the polarization

1 dependency of the gain in the active layer 3 is adjusted
such that thresholds contend between those polarization
modes, the polarization mode of output light can be switched.
In this embodiment, the index controlling layer 4 is
5 composed of material transparent to light amplified
in the active layer 3. The index controlling layer 4
may also be formed of material whose refractive index
can be changed due to quantum confinement Stark effect
(QCSE), Frantz-Keldysh effect or the like when a reverse
10 voltage is applied thereto, since the layer 4 only
needs to have a function for changing the phase of
light propagating through the phase adjusting region 23.
Further, where the index controlling layer 4 is formed of
material whose index can be changed when a current is
15 injected therein, a laser operates similarly to this
embodiment even if the material absorbs or amplifies
the oscillated light, though its performance is slightly
lowered.

In the above device, the coupling coefficient of
20 the second diffraction grating 7 is lowered, and the
reflective layer 14 is formed on the end facet. Hence,
light returning from the phase adjusting region 23
is strengthened relatively to light from the low- κ
region 21, so that the influence of the light returning
25 from the region 23 is increased. Consequently, the
oscillation mode can be efficiently and stably modulated
by the control of the phase adjusting region 23.

1 Second Embodiment

A second embodiment of a DFB semiconductor laser is illustrated in Fig. 4. As illustrated in Fig. 4, a buffer layer 102 of n-InP, an active layer 103, a refractive-index controlling layer 104, a light guide layer 105 of undoped InGaAsP, a clad layer 108 of p-InP, and a contact layer 109 of p-InGaAs are laid down over a substrate 101 of n-InP in this order. A diffraction grating 106 is formed at the interface between the light guide layer 105 and the clad layer 108 in a DFB laser region 120. Further, a set of three first electrodes 110-1, 110-2 and 110-3 and a second electrode 111 are deposited on divided portions of the contact layer 109, and a third electrode 112 is formed on the bottom surface of the substrate 101. An antireflection layer 113 is provided on an end facet of the DFB laser region 120 with the grating 106 in the laser, and a reflective layer 114 is formed on an end facet of a phase adjusting region 121 lacking the grating. Separating grooves 115 are respectively formed between the three first electrodes 110-1, 110-2 and 110-3 and the second electrode 111 for the purpose of electric separation.

In the above structure, a region under the first three electrodes 110-1, 110-2 and 110-3 is the DFB laser region 120, and a region under the second electrode 111 is the phase adjusting region 121. The positional

1 relation between those two regions 120 and 121 is
indicated in Fig. 4. Also in this embodiment, a burying
structure of burying layers is employed as a confining
structure in a direction transverse to a light
5 propagation direction.

The second embodiment is different from the first
embodiment in that the DFB laser region 120 is divided
into plural current-injection regions under the three
first electrodes 110-1, 110-2 and 110-3 and that the
10 diffraction grating 106 is a uniform grating. In this
embodiment, the coupling coefficient of the uniform
grating 106 is set to 40 cm^{-1} , and its pitch is set to
about 240 nm.

The operation of the second embodiment will be
15 described. In this embodiment, when a current injected
into the portion of the DFB laser region 120 directly
adjacent to the phase adjusting region 121 is decreased,
the influence of light returning from the phase adjusting
region 121 is effectively imparted to the oscillation
20 mode of the laser. Thus, the second embodiment
can be operated similarly to the first embodiment,
even though no diffraction gratings with different
coupling coefficients is formed in the laser. If only
such polarization switching operation is desired, the
25 DFB laser region 120 only needs to be divided into two
regions. However, since the DFB laser region 120 is
divided into three regions in the second embodiment, the

1 oscillation wavelength can also be readily controlled
when amounts of currents injected into the two regions
under the two electrodes 10-1 and 10-2 on the side of
the antireflection layer 113 are varied, i.e., uneven
5 current injection is performed.

Third Embodiment

Fig. 5 illustrates a third embodiment of a light
transmitter 300 using an optical device of the present
invention. As illustrated in Fig. 5, the transmitter 300
10 includes a semiconductor laser (LD) 331 of the present
invention, a mode selector 332, such as a polarization-
mode selector (a polarizer), and a controller 330.
Optical coupling means, such as lenses, may be employed
to obtain effective optical couplings between the
15 LD 31 and the mode selector 332 and the like.

The operation of the third embodiment will be
described. The controller 330 receives a transmission
electric signal and supplies a drive signal to the LD 331
so that the polarization mode (TE mode or TM mode)
20 of output light from the device 331 is modulated
corresponding to the electric signal. For that purpose,
a current injected into the phase adjusting region of
the above embodiment is changed, for example. The
mode selector 332 selects one polarization mode from the
25 light output generated by the drive signal. Thus, an
intensity-modulated optical signal can be obtained
corresponding to the transmission electric signal. The

1 thus-constructed transmitter 300 can output the light
intensity signal corresponding to the electric signal.
Therefore, this transmitter can be used as a transmitter
in an optical LAN or the like which performs communication
5 using a light intensity signal.

The mode selector 332 may be a wavelength selector,
such as an optical band-pass filter, when the wavelength
of the output of the semiconductor laser 331 is switched
simultaneously with the switching of the polarization
10 mode.

The following wavelength multiplexing optical
transmission system can also be constructed: A plurality
of optical signals at plural wavelengths are supplied
using a plurality of the above-described semiconductor
15 lasers, plural optical signals are coupled to a single
light transmission line, only a signal at a desired
wavelength is selected in a receiver using a filter
means, such as a tunable band-pass filter, and thus the
desired signal is detected.

20 As described in the foregoing, according to the
present invention, the construction is devised such
that light from the phase controlling region is increased
relative to light from the region adjacent to the phase
controlling region, or the coupling coefficient of the
25 region adjacent to the phase controlling region is
decreased, thereby enhancing the effect of the phase
controlling region.

1 Further, according to the present invention, the
construction is devised such that the amount of current
injected into the region adjacent to the phase controlling
region can be decreased, thereby enhancing the effect of
5 the phase controlling region without controlling the
coupling coefficient of the diffraction grating along
the cavity-axial direction.

Except as otherwise disclosed herein, the various
components shown in outline or block form in the Figures
10 are individually well known in the laser device and
optical communication arts, and their internal
construction and operation are not critical either
to the making or using of this invention or to a
description of the best mode of the invention.

15 While the present invention has been described
with respect to what is presently considered to be the
preferred embodiments, it is to be understood that the
invention is not limited to the disclosed embodiments.
The present invention is intended to cover various
20 modifications and equivalent arrangements included
within the spirit and scope of the appended claims.

1 WHAT IS CLAIMED IS:

1. A laser comprising:

a first region with a first waveguide, said first waveguide including a first diffraction grating;

5 a second region with a second waveguide, said second waveguide including a second diffraction grating; and

a phase controlling region with a third waveguide, said phase controlling region including phase control means for controlling an effective refractive index of
10 said third waveguide, and said phase controlling region, said first region and said second region being serially coupled to each other along a light propagation direction in this order, and being constructed such that light to said first region from said phase controlling region is
15 enlarged relatively to light to said phase controlling region from said first region.

2. A laser according to claim 1, a coupling coefficient of said first diffraction grating in said
20 first region adjacent to said phase controlling region being set smaller than a coupling coefficient of said second diffraction grating in said second region.

3. A laser according to claim 1, said first region
25 further including first control means for pumping said first region, and said phase control means and said first control means being capable of independently controlling

1 said phase controlling region and said first region,
respectively.

4. A laser according to claim 3, said phase control
5 means and said first control means being capable of
independently injecting currents into said phase
controlling region and said first region, respectively.

5. A laser according to claim 1, said first region
10 further including first control means for pumping
said first region, said second region further including
second control means for pumping said second region,
and said first control means and said second control
means being constructed such that a pumping amount
15 of said first region can be smaller than a pumping
amount of said second region.

6. A laser according to claim 1, said laser being
constructed as a distributed feedback semiconductor
20 laser.

7. A laser according to claim 6, said phase
controlling region further including a cleaved end facet.

25 8. A laser according to claim 7, a reflective layer
being provided on said cleaved end facet.

1 9. A laser according to claim 6, said second region
further including an antireflection layer provided on a
cleaved end facet of said second region.

5 10. A laser comprising:

a first region with a first waveguide, said first
waveguide including a first diffraction grating;

a second region with a second waveguide, said second
waveguide including a second diffraction grating; and

10 a phase controlling region with a third waveguide,
said phase controlling region including control means for
controlling an effective refractive index of said third
waveguide, and said phase controlling region, said first
region and said second region being serially coupled
15 along a light propagation direction in this order, and
being constructed such that a coupling coefficient
of said first region adjacent to said phase controlling
region being set smaller than a coupling coefficient of
said second region.

20

11. A laser according to claim 10, said phase
controlling region, said first region and said second
region being constructed such that light to said first
region from said phase controlling region is enlarged
25 relatively to light to said phase controlling region from
said first region.

1 12. A laser according to claim 10, said first region
further including first control means for pumping said
first region, and said phase control means and said first
control means being capable of independently controlling
5 said phase controlling region and said first region,
respectively.

13. A laser according to claim 12, said phase
control means and said first control means being capable
10 of independently injecting currents into said phase
controlling region and said first region, respectively.

14. A laser according to claim 10, said first region
further including first control means for pumping said
15 first region, said second region further including second
control means for pumping said second region, and said
first control means and said second control means being
constructed such that a pumping amount of said first
region can be smaller than a pumping amount of said
20 second region.

15. A laser according to claim 10, said laser being
constructed as a distributed feedback semiconductor
laser.
25

16. A laser according to claim 15, said phase
controlling region further including a cleaved end facet.

1 17. A laser according to claim 16, a reflective layer
being provided on said cleaved end facet.

 18. A laser according to claim 15, said second region
5 further including an antireflection layer provided on a
cleaved end facet of said second region.

 19. A method for driving a laser, said method
comprising the steps of:
10 preparing a laser including:
 a first region with a first waveguide, said
first waveguide including a first diffraction grating;
 a second region with a second waveguide,
said second waveguide including a second diffraction
15 grating; and
 a phase controlling region with a third waveguide,
said phase controlling region including phase control
means for controlling an effective refractive index of
said third waveguide, and said phase controlling region,
20 said first region and said second region being serially
coupled to each other along a light propagation direction
in this order, and being constructed such that light to
said first region from said phase controlling region is
enlarged relatively to light to said phase controlling
25 region from said first region; and
 changing a current injected into or a reverse
voltage applied to the phase controlling region to change

1 at least one of a polarization mode and a waveguide of
light output from the laser.

20. A light transmitter comprising:

5 a laser including:

a first region with a first waveguide, said
first waveguide including a first diffraction grating;

a second region with a second waveguide,
said second waveguide including a second diffraction
10 grating; and

a phase controlling region with a third waveguide,
said phase controlling region including phase control
means for controlling an effective refractive index of
said third waveguide, and said phase controlling region,
15 said first region and said second region being serially
coupled to each other along a light propagation direction
in this order, and being constructed such that light to
said first region from said phase controlling region is
enlarged relatively to light to said phase controlling
20 region from said first region;

control means for controlling light output from said
laser in accordance with a transmission signal; and

a mode selector for selecting a component of a
desired mode from the light output from said laser.

25

21. A light transmitter according to claim 20, said
mode selector comprising a polarization-mode selector.

1 22. A light transmitter according to claim 20, said
mode selector comprising a wavelength selector.

23. An optical communication system for
5 communicating over a light transmission line that transmits
a signal from a transmitter side to a receiver side, said
system comprising:

a light transmitter for transmitting light of a
signal through the light transmission line including:

10 a laser including:

a first region with a first waveguide, said
first waveguide including a first diffraction grating;

a second region with a second waveguide,
said second waveguide including a second diffraction
15 grating; and

a phase controlling region with a third waveguide,
said phase controlling region including phase control
means for controlling an effective refractive index of
said third waveguide, and said phase controlling region,
20 said first region and said second region being serially
coupled to each other along a light propagation direction
in this order, and being constructed such that light to
said first region from said phase controlling region is
enlarged relatively to light to said phase controlling
25 region from said first region;

control means for controlling light output
from said laser in accordance with a transmission

1 signal; and

a mode selector for selecting a component
of a desired mode from the light output from said
laser; and

5 a receiver for receiving and detecting an
intensity-modulated signal transmitted from the laser
through the light transmission line.

24. An optical communication system according to
10 claim 23, said system being a wavelength division
multiplexing optical communication system, in which the
light transmission line transmits a plurality of
intensity-modulated signals at a plurality of wavelengths
generated by a plurality of said transmitters, and a
15 wavelength selector selects the intensity-modulated signal
at a desired wavelength to be detected on a side of said
receiver.

20

25

1 ABSTRACT OF THE DISCLOSURE

A laser includes a first region with a first waveguide having a first diffraction grating, a second region with a second waveguide having a second
5 diffraction grating, and a phase controlling region with a third waveguide and a phase control unit for controlling an effective refractive index of the third waveguide. The phase controlling region, the first region and the second region are coupled serially
10 along a light propagation direction in this order, and are constructed such that light to the first region from the phase controlling region is enlarged relatively to light to the phase controlling region from the first region, or constructed such that a coupling
15 coefficient of the first diffraction grating in the first region adjacent to the phase controlling region is smaller than a coupling coefficient of the second diffraction grating in the second region away from the phase controlling region.

20

25

FIG.1

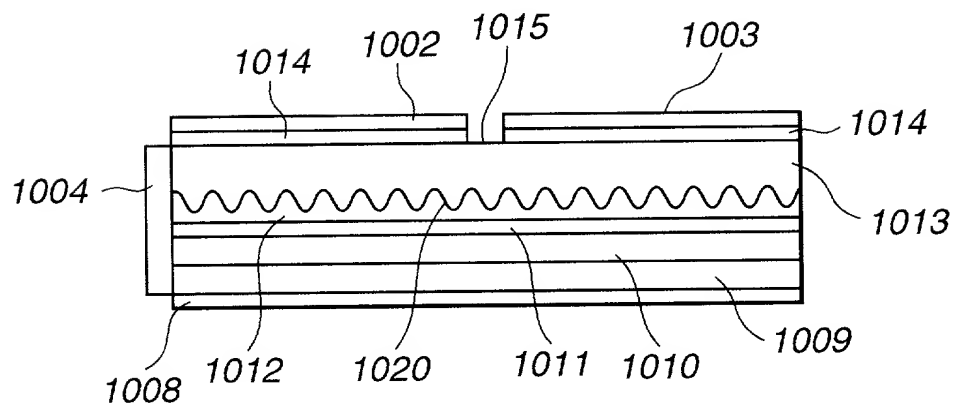


FIG.2

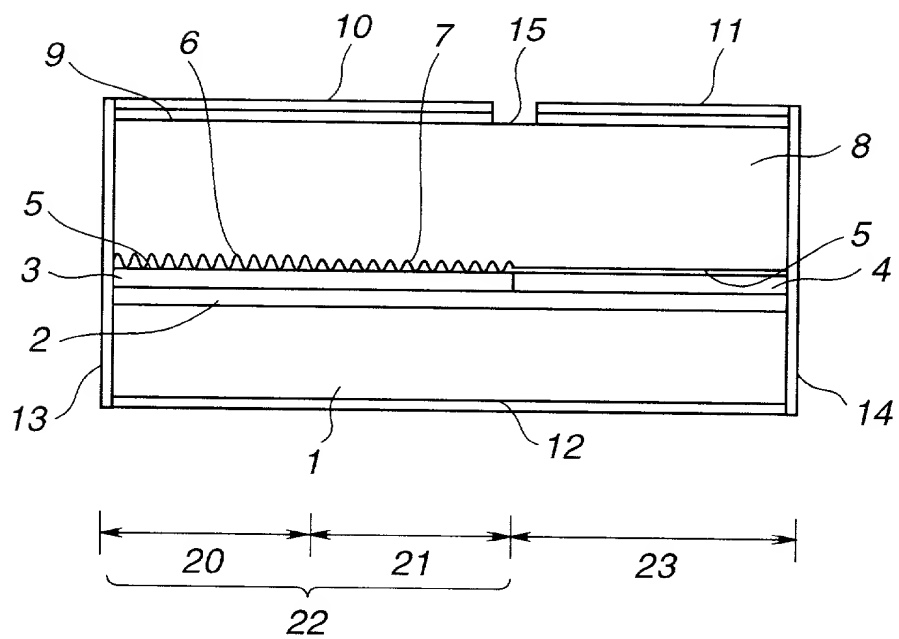


FIG.3

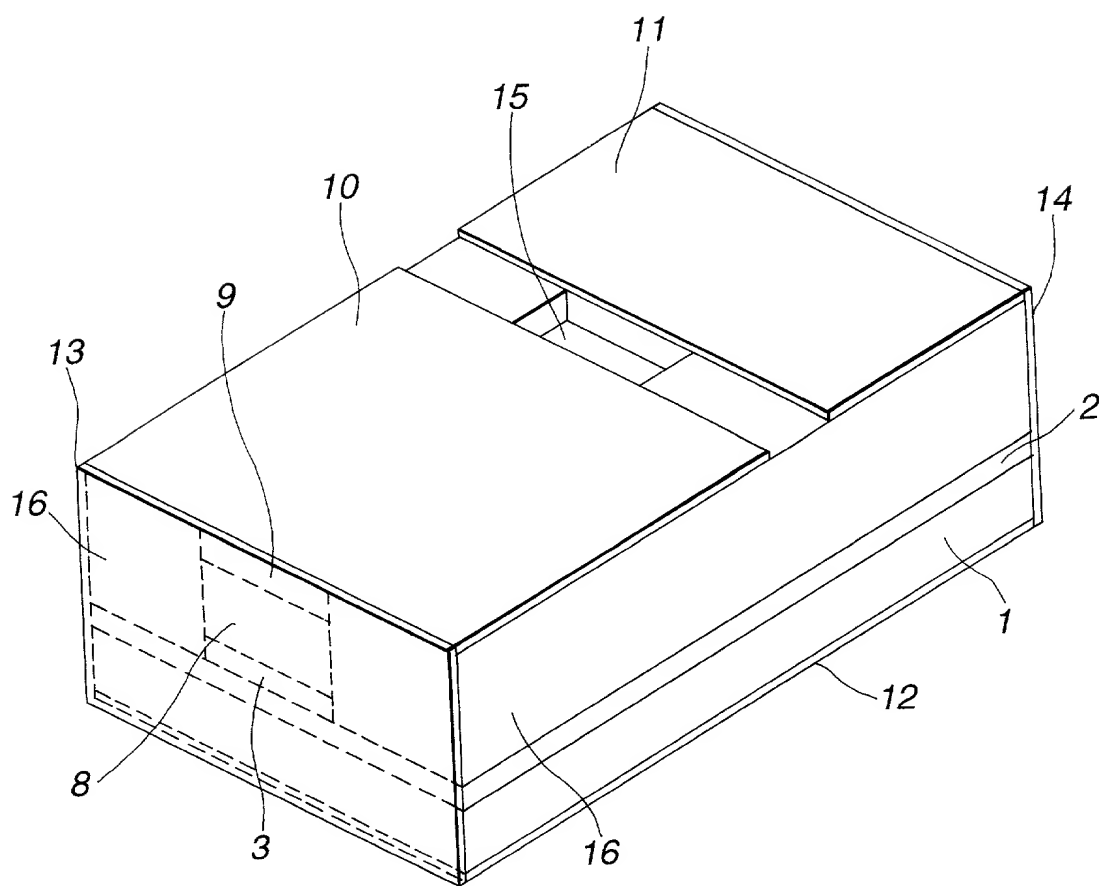


FIG.4

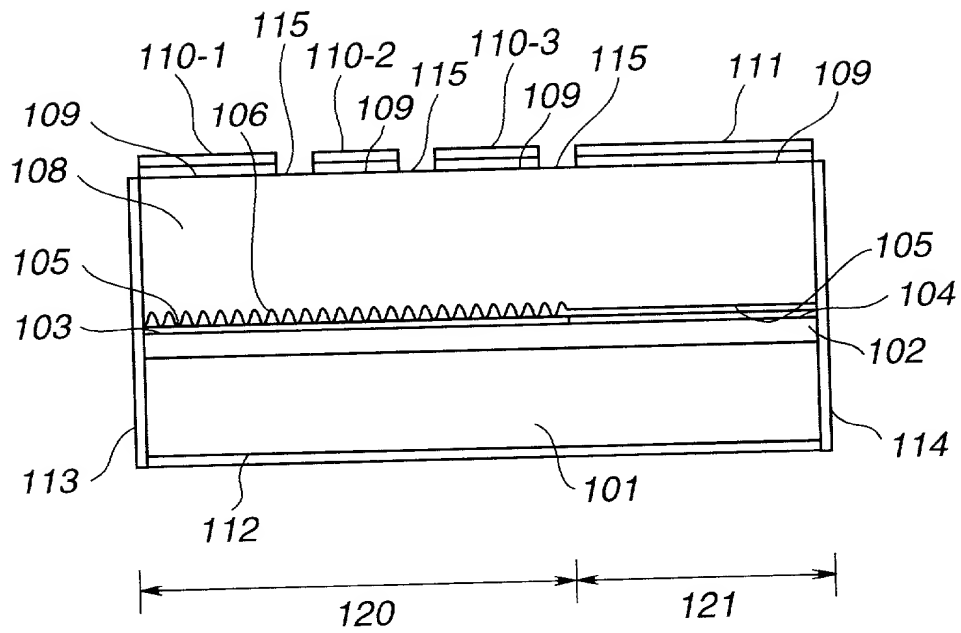
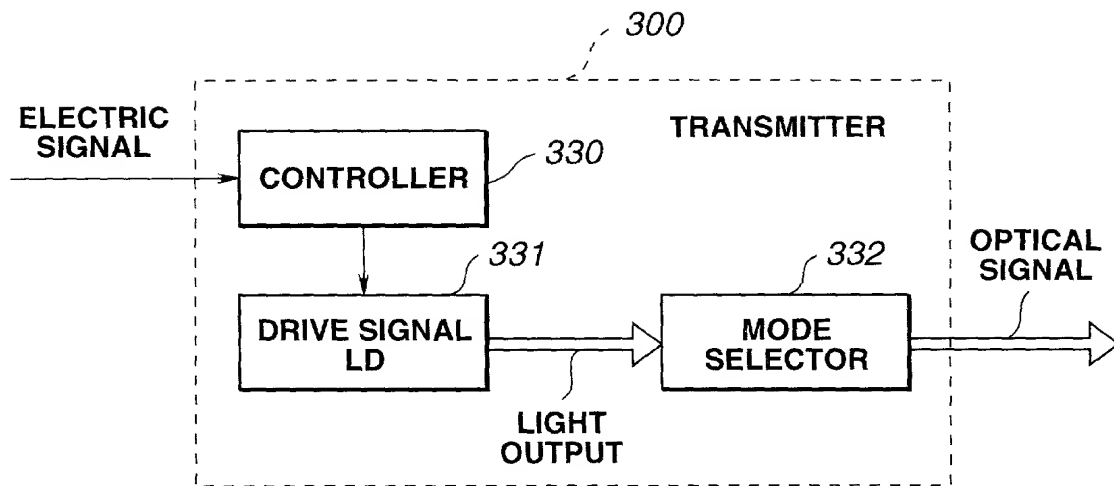


FIG.5



**COMBINED DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION**
(page 1)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled LASER WITH PHASE CONTROLLING REGION AND METHOD FOR DRIVING THE SAME

the specification of which ☒ is attached hereto. ☐ was filed on _____ as United States Application No. or PCT International Application No. _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I hereby claim foreign priority benefits under 35 U.S.C. §119(a)-(d) or §365(b), of any foreign application(s) for patent or inventor's certificate, or §365(a) of any PCT international application which designates at least one country other than the United States, listed below and have also identified below any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed:

Country	Application No.	Filed (Day / Mo. / Yr.)	(Yes / No) Priority Claimed
Japan	90991/1998 (Pat.)	19/March/1998	Yes

I hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or §365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. §112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 C.F.R. §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

Application No.	Filed (Day/Mo./Yr.)	Status (Patented, Pending, Abandoned)

I hereby appoint the practitioners associated with the firm and Customer Number provided below to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to the address associated with that Customer Number:

FITZPATRICK, CELLA, HARPER & SCINTO
Customer Number: 05514

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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